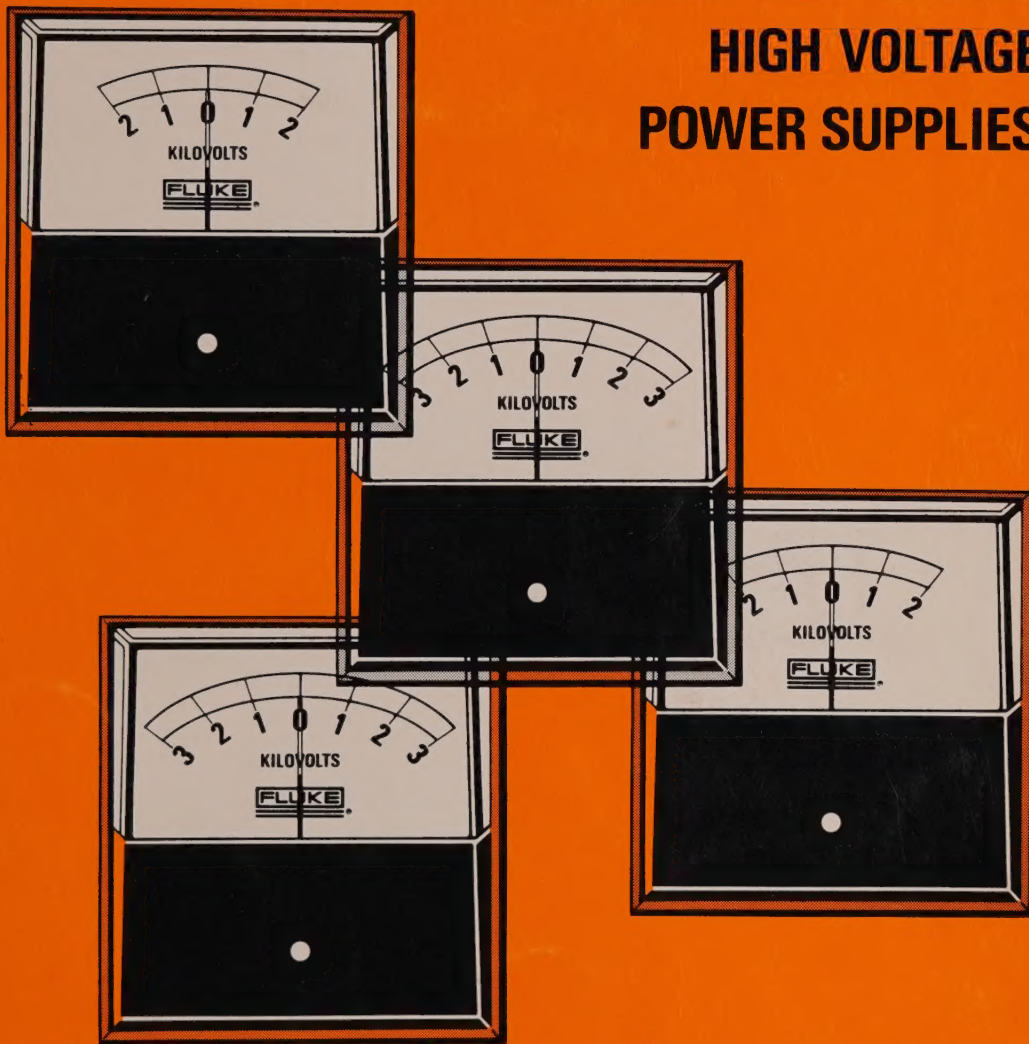
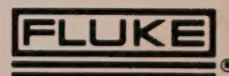


MODELS 412B & 415B HIGH VOLTAGE POWER SUPPLIES



STUDENT HANDOUT

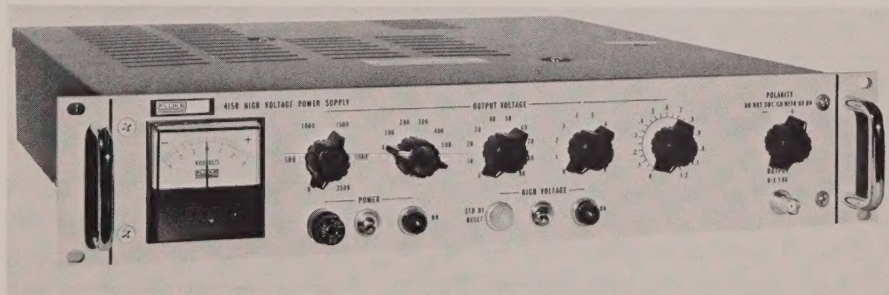


Foreword

This training course has been prepared by the Customer Service Department of the John Fluke Mfg. Co., Inc. to assist the experienced technician to understand how the instrument works, how to calibrate it and how to maintain it. Should you have any questions, comments or suggestions about this course of instruction please feel free to communicate them to the Training Department by letter or telephone.



MODEL 412B



MODEL 415B

**CUSTOMER SERVICE TRAINING DEPT.
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INTRODUCTION

The Model 412B can supply dc voltages to ± 2100 volts while the Model 415B is capable of ± 3100 volts dc. A summary of the principal differences in specifications between the two instruments will be found in Table 1.

Table 1. 412B AND 415B DIFFERENCES

412B		415B
$\pm 2100\text{Vdc}$	Output Voltage	$\pm 3100\text{Vdc}$
0.001%	Line Regulation	0.0005%
0.001%	Load Regulation	0.0005%
$>500\mu\text{Vrms}$	Ripple	$>100\mu\text{Vrms}$
$\pm 0.005\%/hr.$	Stability	$\pm 0.002\%/hr.$
$\pm 0.02\%/day$		$\pm 0.01\%/day$

This student handout is organized into three parts. The first part is titled Theory of Operation. The following parts are titled Calibration Notes and Troubleshooting Notes.

THEORY OF OPERATION

Since the circuit differences between the two instruments are slight, investigation will concentrate upon the 415B. Investigation will begin with a basic discussion of a high voltage power supply in terms of a simplified diagram. This will be followed by a block diagram showing the organization of the 412B and 415B High Voltage Power Supplies. Each block will then be discussed in terms of the schematic diagrams at the rear of this student handout.

The Basic High Voltage Power Supply (Figures 1 and 2)

Referring to Figure 1, note the polarity across the high voltage supply and series pass element. The resulting dc voltage at the output terminals will be the difference between these opposing potentials. Consequently, the output voltage can be varied, ideally, from zero to the potential of the high voltage supply by simply controlling the conduction of the series regulator. Control of the series regulator is accomplished by the error amplifier, which together with the high voltage supply, series regulator, reference voltage, reference divider and voltage control resistor form a dc operational amplifier. Therefore, the output of the amplifier will be equal to the ratio of the voltage control resistor to the reference divider resistor times the reference voltage. Since the reference voltage and the reference divider resistor values are constant, changes in the output voltage can be accomplished by varying the voltage control resistor. Changing the value of the voltage control resistor causes an unbalance between the

input terminals to the error amplifier. This results in the error amplifier causing the conduction of the series regulator to change until a balance between the two amplifier input terminals is achieved, resulting in a new output voltage. These same operating principles apply to the Fluke High Voltage Power Supplies.

Figure 2 illustrates the organization of the Fluke High Voltage Power Supplies. The high voltage transformer and high voltage rectifier constitute the high voltage supply of Figure 1. In a similar manner, the series pass element and the series regulator of Figure 1 coincide. The error sensing and control block correspond to the reference voltage, reference divider, and voltage control resistor of Figure 1. In addition to the basic building blocks of the high voltage supply in Figure 2, other functions are also provided. Circuit operating voltages are provided by the Auxiliary Supply. Sufficient time for vacuum tube filaments to heat is provided by the Time Delay. Protection from overloads is accomplished by the Overcurrent circuit. Let's take a look at each of these blocks in more detail.

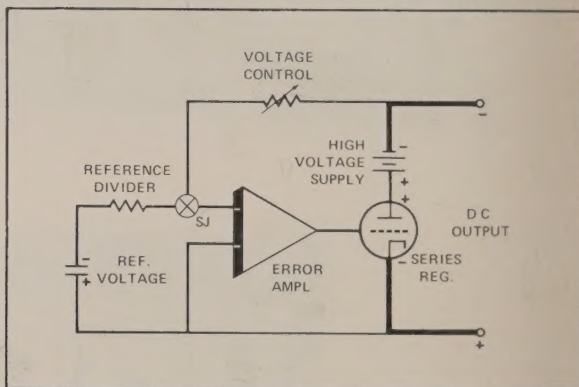


Figure 1. The Basic Idea

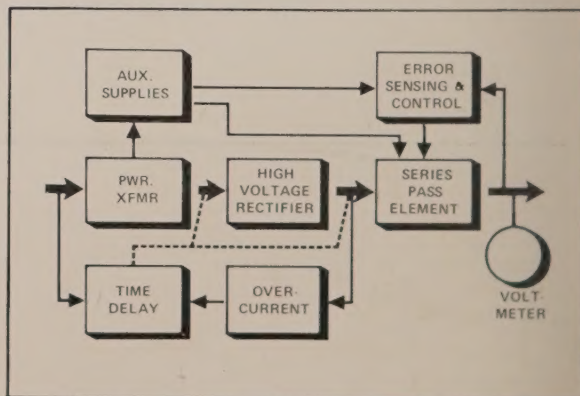


Figure 2. 412B and 415B Basic Block Diagram

Power Transformer And High Voltage Rectifier (Schematic 1)

Input line voltage is stepped up by the high voltage transformer and applied to the high voltage rectifier. When rectified, this voltage is applied to the voltage doubler configuration of C7 and C8. Note that the center of the doubler is connected to S3A which selects the appropriate high voltage tap on the power transformer. This arrangement allows the series pass element to operate more efficiently on the lower voltage ranges. The same arrangement is used in the 412B except that there are fewer taps and rectifiers due to the lower output voltage capabilities.

Series Pass Element (Schematic 1)

The filtered but unregulated dc voltage from the voltage doubler is applied to series pass tubes V1 and V2. Conduction of these parallel connected vacuum tubes is controlled by the error amplifier. Output voltage from the supply is dependent upon the voltage across the series pass element, such that the degree of conduction determines the output voltage of the supply.

Error Sensing And Control (Figure 3)

Figure 3 shows a block diagram of the circuits involved in the sensing and control of the output voltage. With the Error Amplifier connected between the positive output bus and the summing junction, any difference between these points will be amplified for control of the series pass element. The Reference Tube provides a constant voltage source to work in conjunction with the Reference Divider Resistors and Rheostat to provide the Error Amplifier with a stable reference point. Operating voltages for the Reference Tube and Error Amplifier are provided by the 125 Volt Regulator.

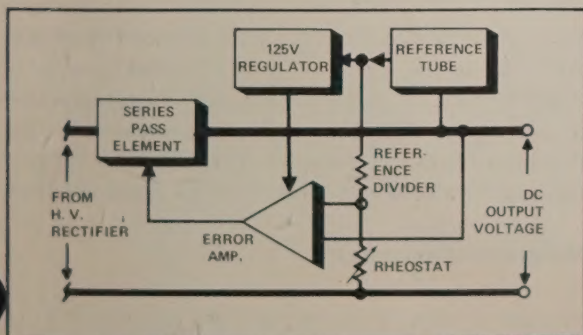


Figure 3. Error Sensing and Control Simplified Diagram

ERROR AMPLIFIER (Schematic 2)

The input stage of the Error Amplifier is a differential pair, Q8 and Q7. Transistor Q8's base is connected to the summing junction through R25, while Q7's base is connected through R20 to the positive output bus. Any difference between these two points is seen as a collector current change in Q8. This change is amplified by Q6. A portion of the output from Q6 is fed back to Q7 for loop stabilization. The remaining output is applied to Q3 and Q4, which provides sufficient current drive and impedance match from Q6 to Q2. The cascaded common base arrangement of Q1 and Q2 provides the voltage gain necessary to drive the grids of the series pass tubes V1 and V2.

125 VOLT REGULATOR AND REFERENCE TUBE (Schematic 2)

The 125 Volt Regulator provides operating voltages for the Error Amplifier and Reference Tube. The Reference Tube, in return, supplies the reference voltage for the 125 Volt Regulator. This Reference Tube, A6V1, is factory selected and temperature compensated by resistors R14 and R15. The constant output voltage from the Reference Tube is applied directly to the base of Q5 in the 125 Volt Regulator. The base of Q4 is connected through a voltage divider to the output line of the 125 Volt Supply. Since these transistors form a differential pair, any change in the output voltage will be detected and coupled directly to Q3 for amplification. Transistor Q3 then drives the series pass element, Q1, to bring the supply back to its nominal level. Transistor Q2 acts as a constant voltage source for Q3 and Q4. Zener diode CR1 provides a regulated voltage for the Q3 and also affords some protection for the series pass element, Q1.

REFERENCE DIVIDER AND RHEOSTAT (Schematic 2 and 3)

Reference Tube V1 causes a constant current (2 mA nominal) to flow through the Reference Divider and Rheostat. The Reference Divider, A3R1 through A3R4 and A6R26, allows for precise calibration of the reference current from the Reference Tube. The Voltage Control network, A3R5 through A3R23 (Schematic 3), is a five decade resistive network that provides control of feedback to the Error Amplifier for control of the output voltage. Since the summing junction is always at zero volts, the output voltage will be equal to the constant current (2 mA nominal) times the resistance of the Rheostat.

Auxiliary Supply (Schematic 1)

Operating voltages for the instrument come from the Auxiliary Supply. This supply consists of a full-wave rectifier and voltage double circuit; A5CR1, A5CR2, A6C1 and A6C2. The unregulated voltage from the rectifiers is applied to a voltage divider consisting principally of Zener diode regulators, A5CR3 through A5CR6.

The positive and negative output voltages are referenced to the center of the voltage doubler which is tied to the positive output bus. This allows the supply to float at the potential of the positive output bus.

Time Delay (Schematic 4)

The Time Delay circuit allows a 20 second delay from initial turn on of the high voltage supply until the high voltage can be switched on. This allows time for the filaments of the Series Pass Tubes to come to operating temperature.

When power is applied to the instrument through S1, a part of it is rectified and filtered by CR1, R3, R1, and C1 to provide operating voltages for the delay circuit. When S1 is closed, DS1 is illuminated and current flows through normally closed K2A to the heater of the Time Delay relay, K1. After 20 seconds, K1 pulls in and provides a path to relay K2. With K2 energized, contact K2A opens and K2B closes. This takes the delay relay out of the circuit. With K2B closed, a path is provided that keeps K2 energized. Relay contact K2B also completes the path to the Standby Reset lamp. As soon as the Standby Reset lamp illuminates the High Voltage switch can be set to on. This directs current from the Standby Reset lamp to the High Voltage ON lamp and the K3 and K4 relays. Energizing the K3 and K4 relays causes their respective contacts to close, thus completing the negative bus output path of the High Voltage Supply (See Schematic 1).

Overcurrent (Schematic 1)

Overcurrent relay A7K1 is in the negative output bus of the High Voltage Supply. This relay is preset to energize at a particular trip point which is dependent upon the setting of A4R5. When the current drawn from the supply reaches the trip point, the A7K1 contact closes across A4K2 coil in the Time Delay circuit (See Schematic 4). This causes A4K2 to de-energize and open the path via the K2B contact to the negative output bus relays K3 and K4, thus disabling

the output voltage. With A4K2 de-energized, the path to the delay relay heater is again closed. However, even when the 20 second delay period is completed, A4K2 cannot be energized until the High Voltage switch is placed in the Standby Reset position.

Voltmeter (Schematic 5)

The voltmeter circuit provides an indication of the output voltage from the supply. Over all accuracy of the meter is approximately 3%, which includes the tolerances of the multiplier resistors A3R24 and A3R25 and shunt resistors A3R26 and A3R27. Calibration of the voltmeter is accomplished by A3R26.

CALIBRATION NOTES

Both the 412B and 415B have only three calibration adjustments. These are the high voltage output adjustment, overload current adjustment, and the voltmeter calibration adjustment. The following notes about these adjustments are intended only to familiarize the technician with function, schematic location, and physical location. The following discussion should not be used as a replacement for the calibration procedure in the instruction manual.

High Voltage Adjustment

Before making the high voltage adjustment, the instrument should be operated for at least one hour with covers installed and the maximum output voltage dialed on the front panel. For 415B, the high voltage adjustment is A6R26, whose schematic and physical location is shown in Figure 4. Access to A6R26 is through the top cover and should be adjusted with an insulated screwdriver. The instrument output is dialed to 3000 volts and A6R26 is adjusted for a 3000 volt output from the supply ± 100 millivolts.

High voltage adjustment in the 412B is accomplished with R425, whose schematic and physical location is shown in Figure 5. Access to R425 is also through the top cover and should be adjusted with an insulated screwdriver. The instrument output is dialed to 2000 volts and R425 is adjusted for a 2000 volt output from the supply ± 2 volts.

Voltmeter Adjustment

In order to calibrate the voltmeter the top cover must be removed. Before removing the cover, disable the high voltage by setting the HIGH VOLTAGE switch to the STDBY

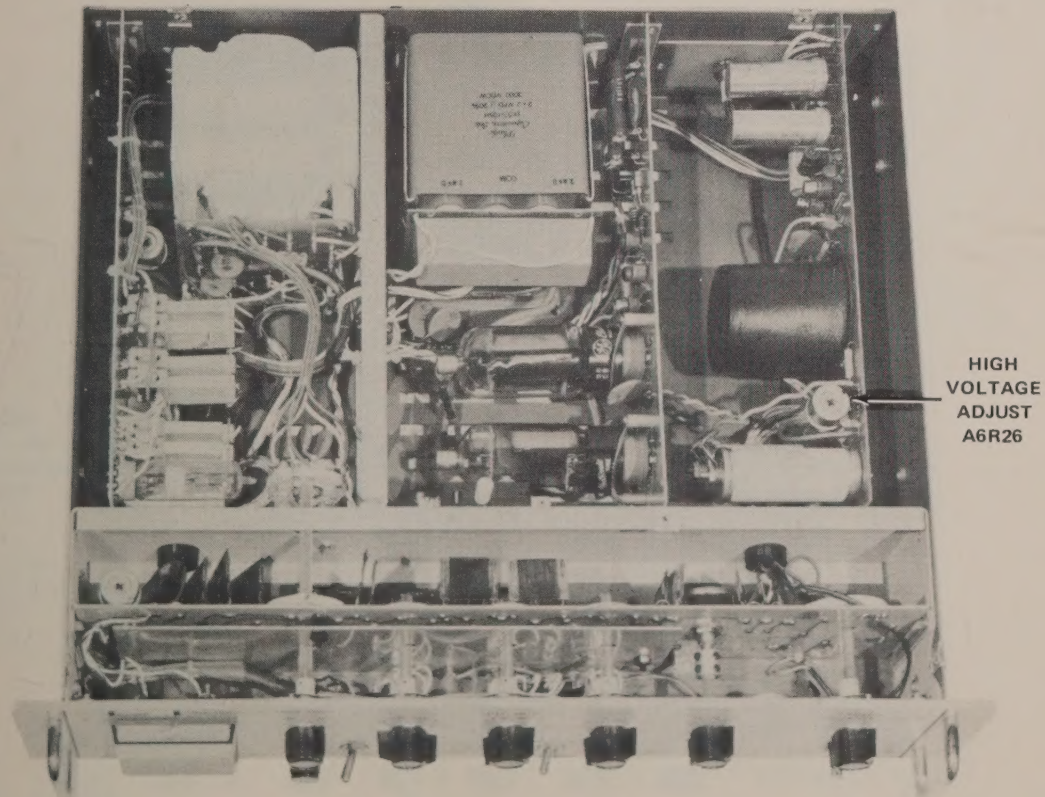
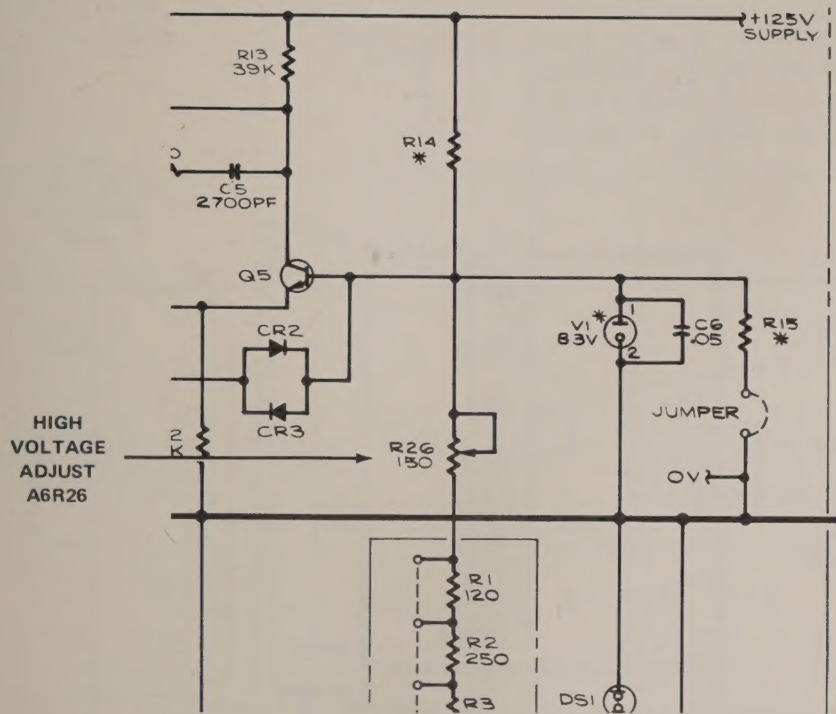


Figure 4. Model 415B High Voltage Adjust Location

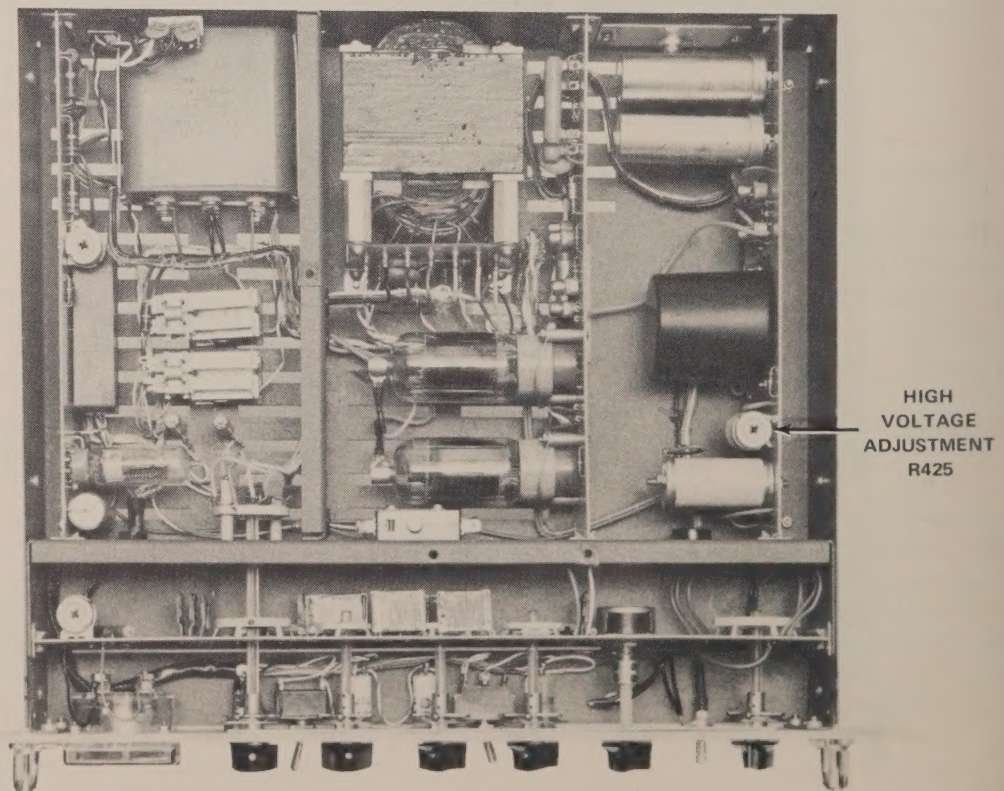
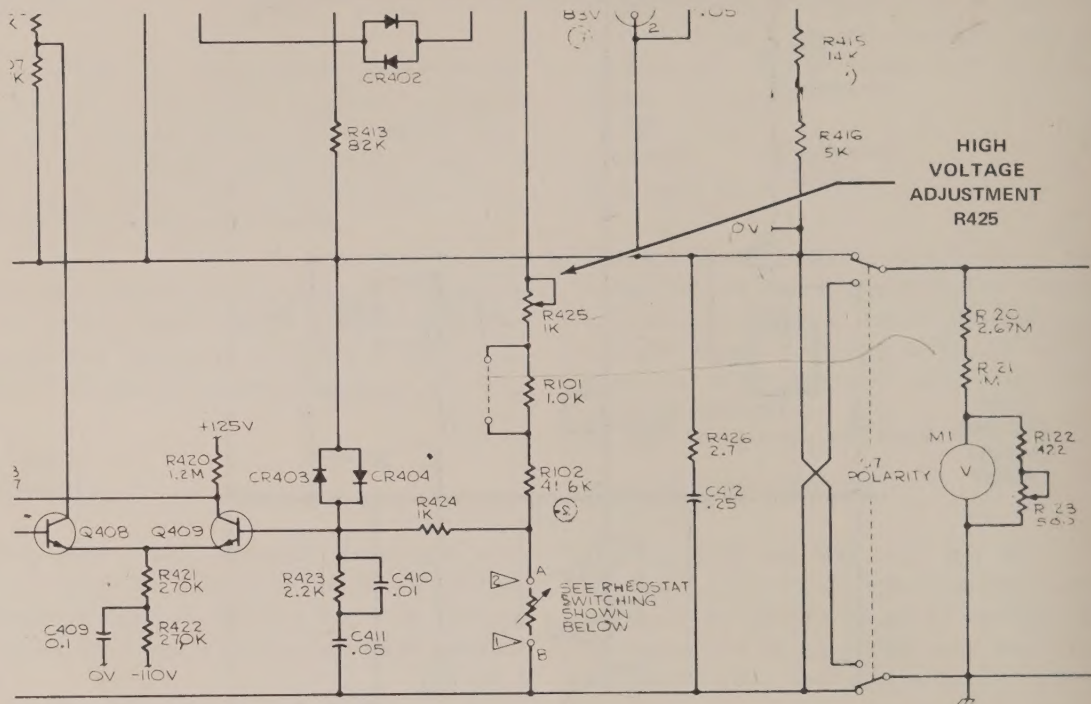


Figure 5. Model 412B High Voltage Adjustment Location

RESET position. With the cover removed, it is necessary to "cheat" the interlock. When making the voltmeter adjustment in either instrument, be sure to use an insulated screwdriver.

To prepare the 415B for adjustment, set the HIGH VOLTAGE switch to the ON position and set the OUTPUT VOLTAGE dials to 3000 volts. The voltmeter adjustment is A3R26, whose schematic and physical location is shown in Figure 6. Adjust A3R26 for a panel meter indication of 3000 volts ± 90 volts.

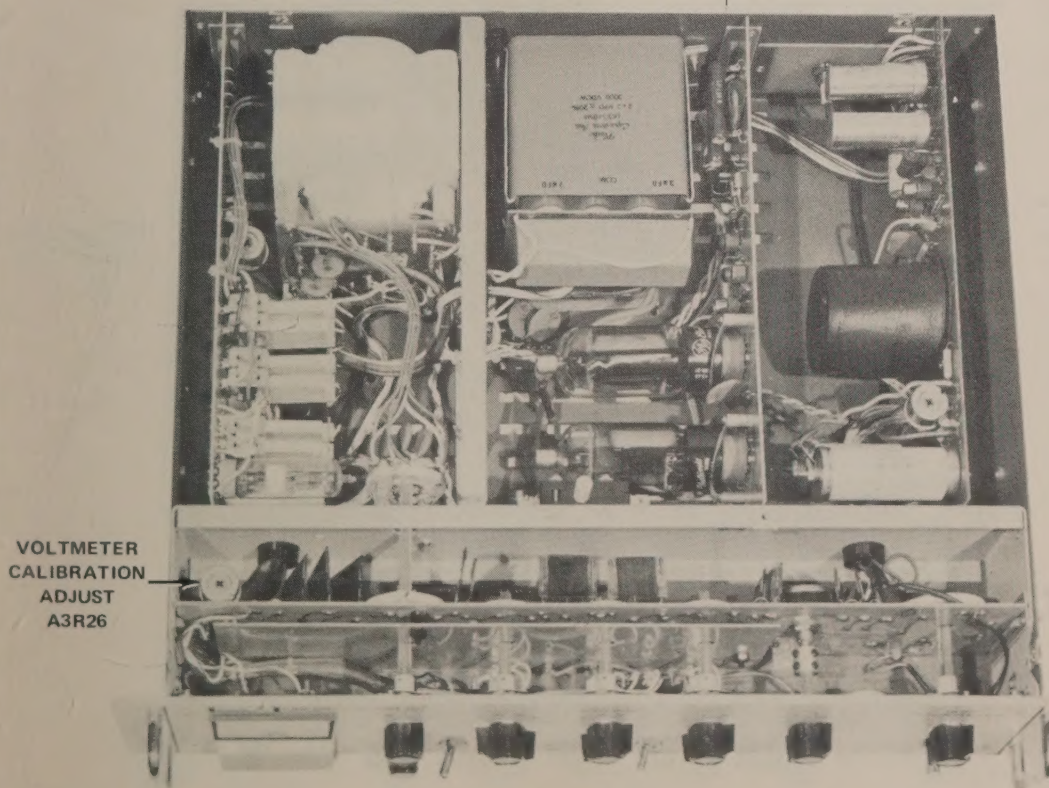
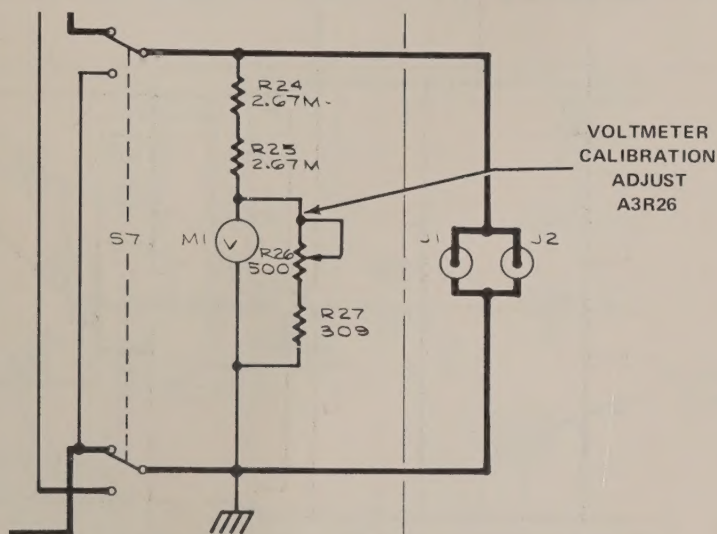


Figure 6. Model 415B Voltmeter Adjustment Location

To prepare the 412B for adjustment, set the HIGH VOLTAGE switch to the ON position and set the OUTPUT VOLTAGE dials to 2000 volts. The voltmeter adjustment

is R123, whose schematic and physical location is shown in Figure 7. Adjust R123 for a panel meter indication of 2000 volts ± 50 volts.

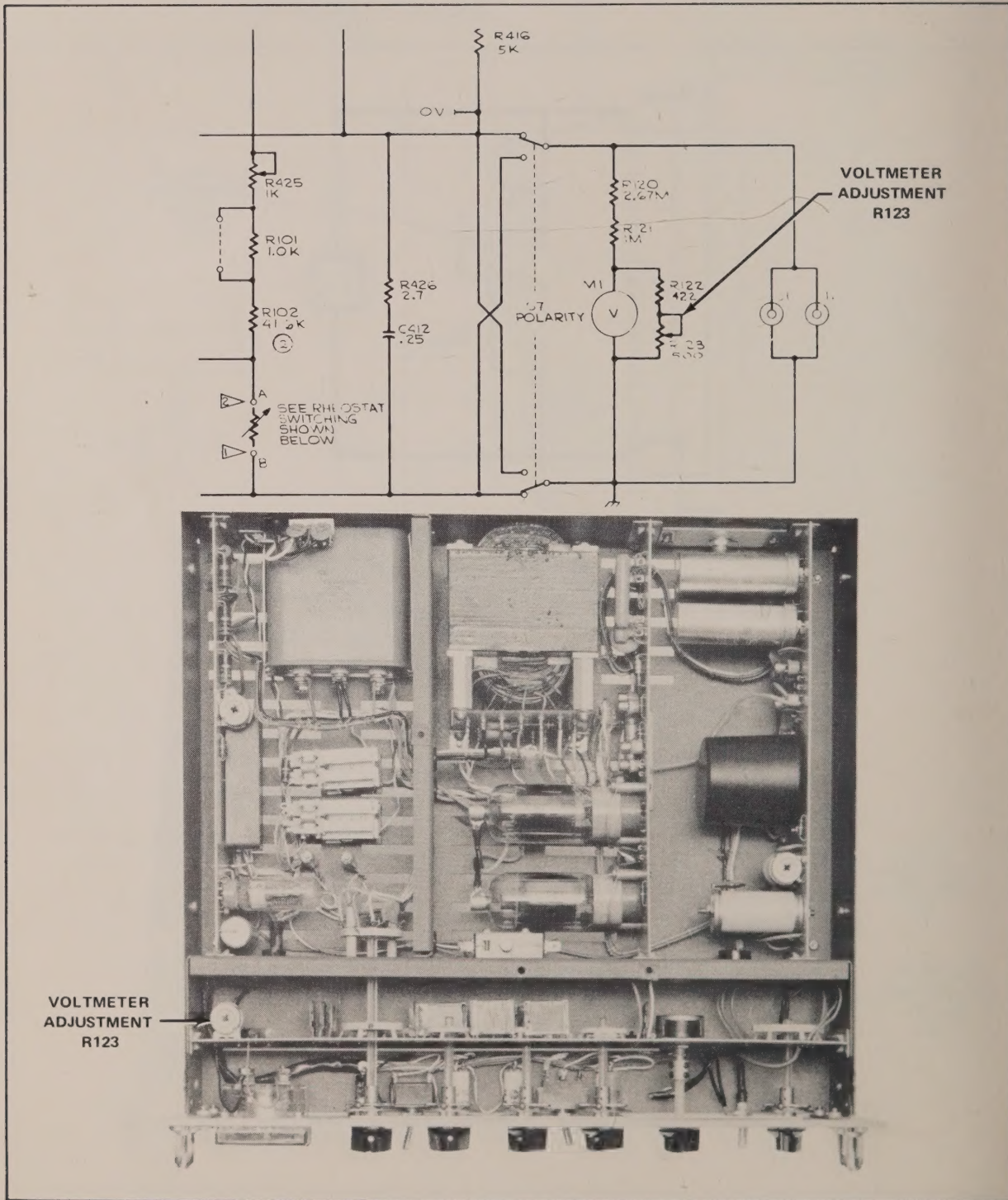


Figure 7. Model 412B Voltmeter Adjustment Location

Overload Current Adjust

Before performing the overcurrent adjustment, the top cover must be removed and the interlock "cheated". This adjustment sets the trip point for the Overcurrent relay. The procedure for adjustment is the same for both the 412B and 415B. A load is connected to the output terminals

that will draw approximately 32 milliamperes, or lower if desired. The overload adjustment is then turned until the Overcurrent relay trips.

The schematic and physical location of the 412B adjustment (R208 for K202) is shown in Figure 8. The schematic location and physical location of the 415B adjustment (A4R5 for A7K1) is shown in Figure 9.

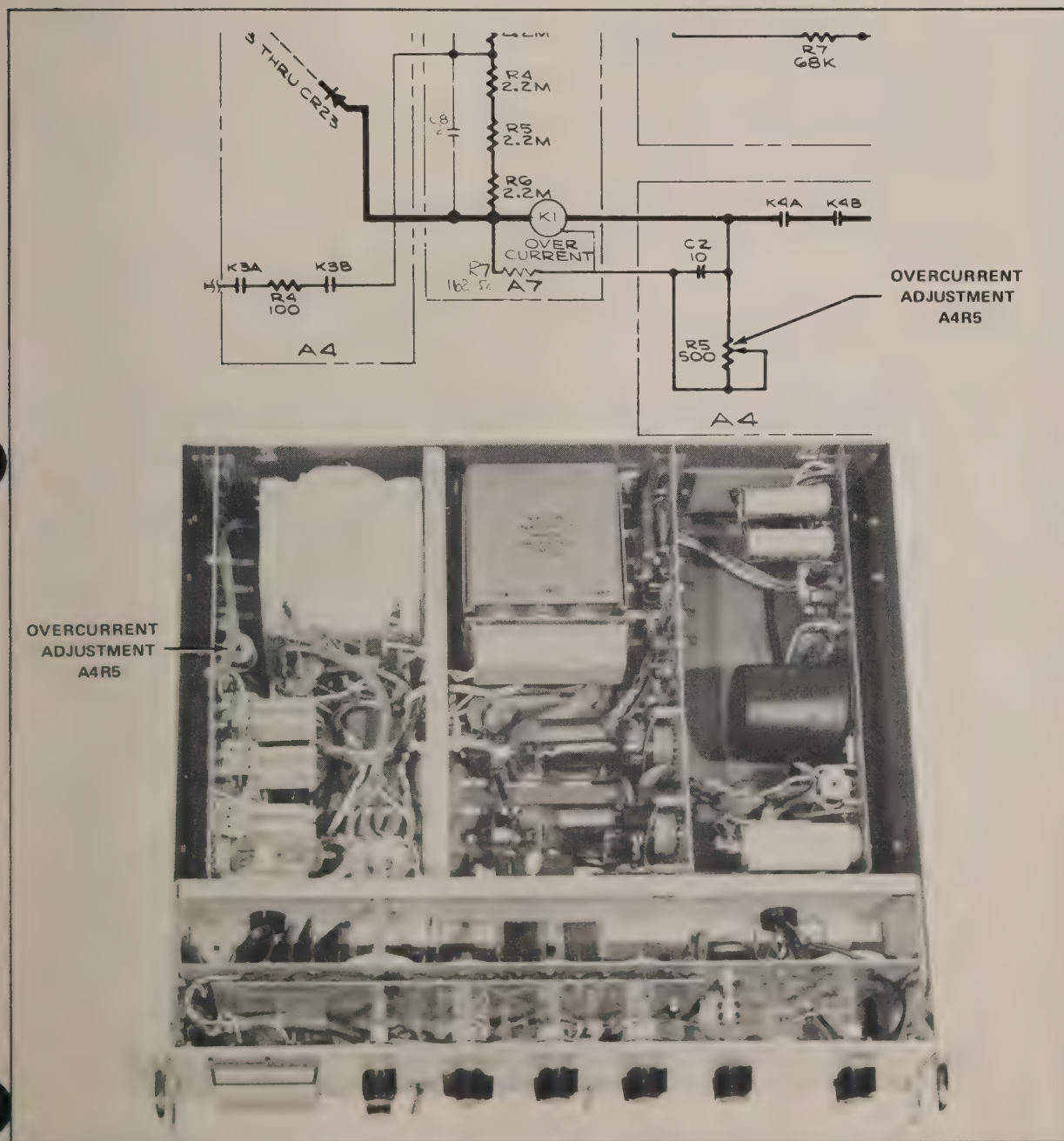


Figure 8. Model 412B Overload Current Adjustment Location

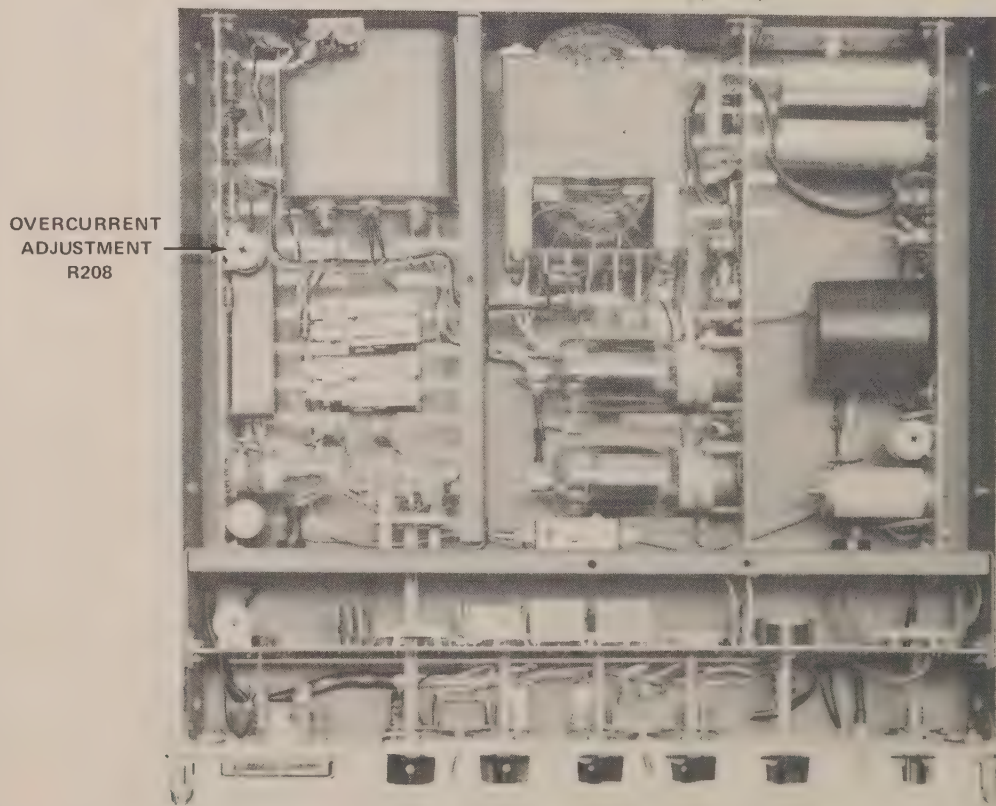
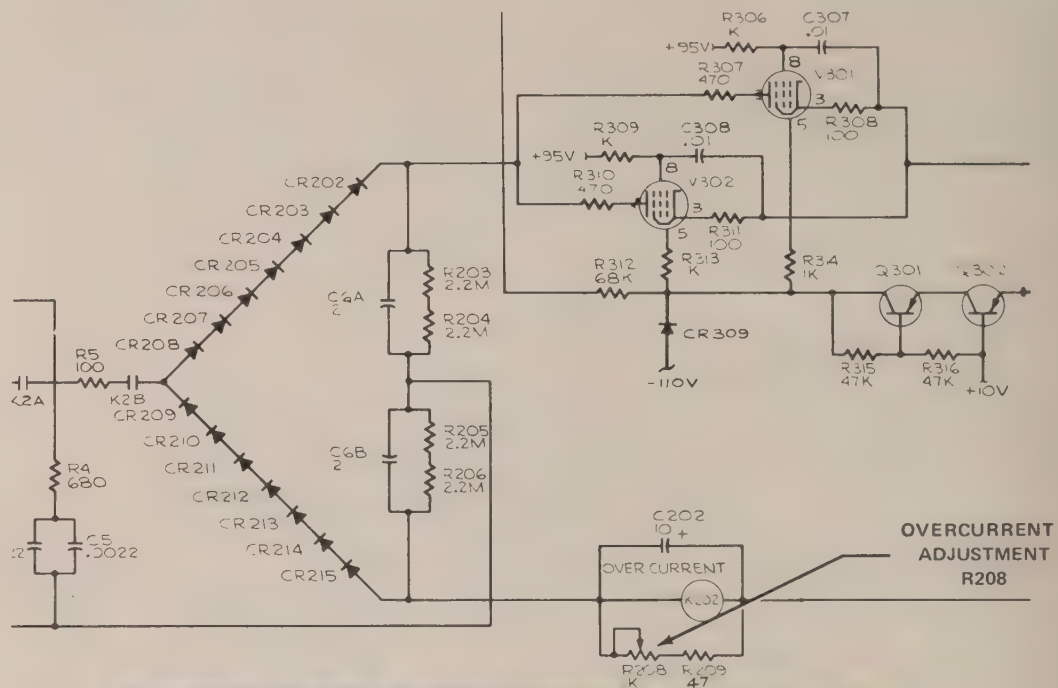


Figure 9. Model 412B Overload Current Adjustment Location

TROUBLESHOOTING NOTES

As an aid to troubleshooting the Model 412B and 415B, keep in mind the overall block diagrams. These diagrams are repeated in Figures 10 and 11. Remember that the major elements for the operational amplifier loop (High Voltage supply, Series Pass, and Error Sensing and Control circuits) can be isolated from each other by pulling the Series Pass Tubes. This allows these circuits to be tested separately for localizing the problem area.

Improper operation of these instruments can produce high voltage transients within the instruments. These transients can cause a "chain reaction" of component failures in more

than one of the major circuit areas. Therefore, if damaged components are found in one area, the other major circuit areas should be tested separately before setting the HIGH VOLTAGE switch to ON.

In general, a "dead" instrument can be related to the Time Delay area. A no output condition can result from a malfunction in the Power Transformer/High Voltage Rectifier area. Low or uncontrollable output can be caused by the Error Sensing and Control circuits or Series Pass. Output tolerance errors can be attributed to the Reference Tube, Reference Divider, or Voltage Control Resistors. It must be emphasized that these problem/probable location areas discussed above are generalizations. They should not be considered as the solution to the problem.

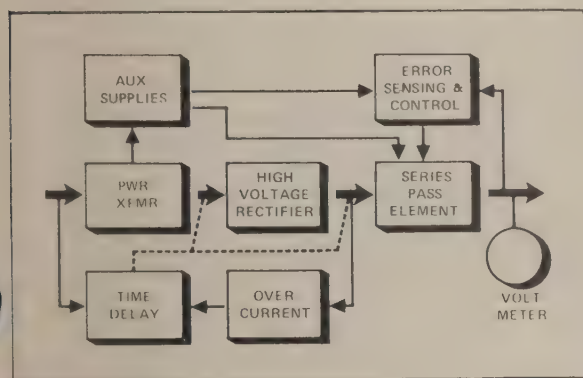


Figure 10. 412B and 415B Basic Block Diagram

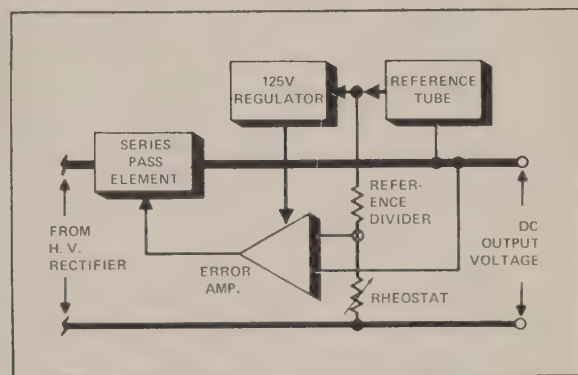
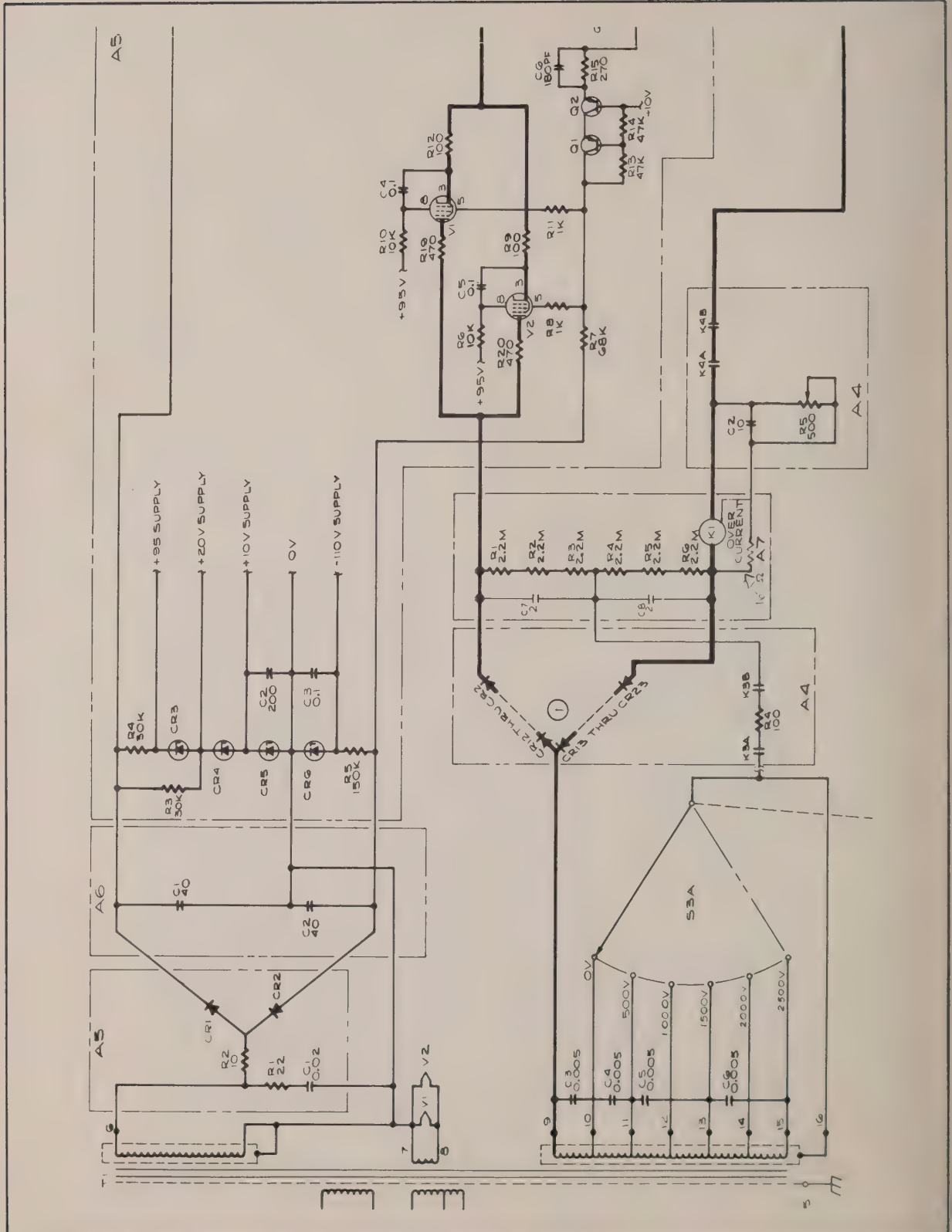
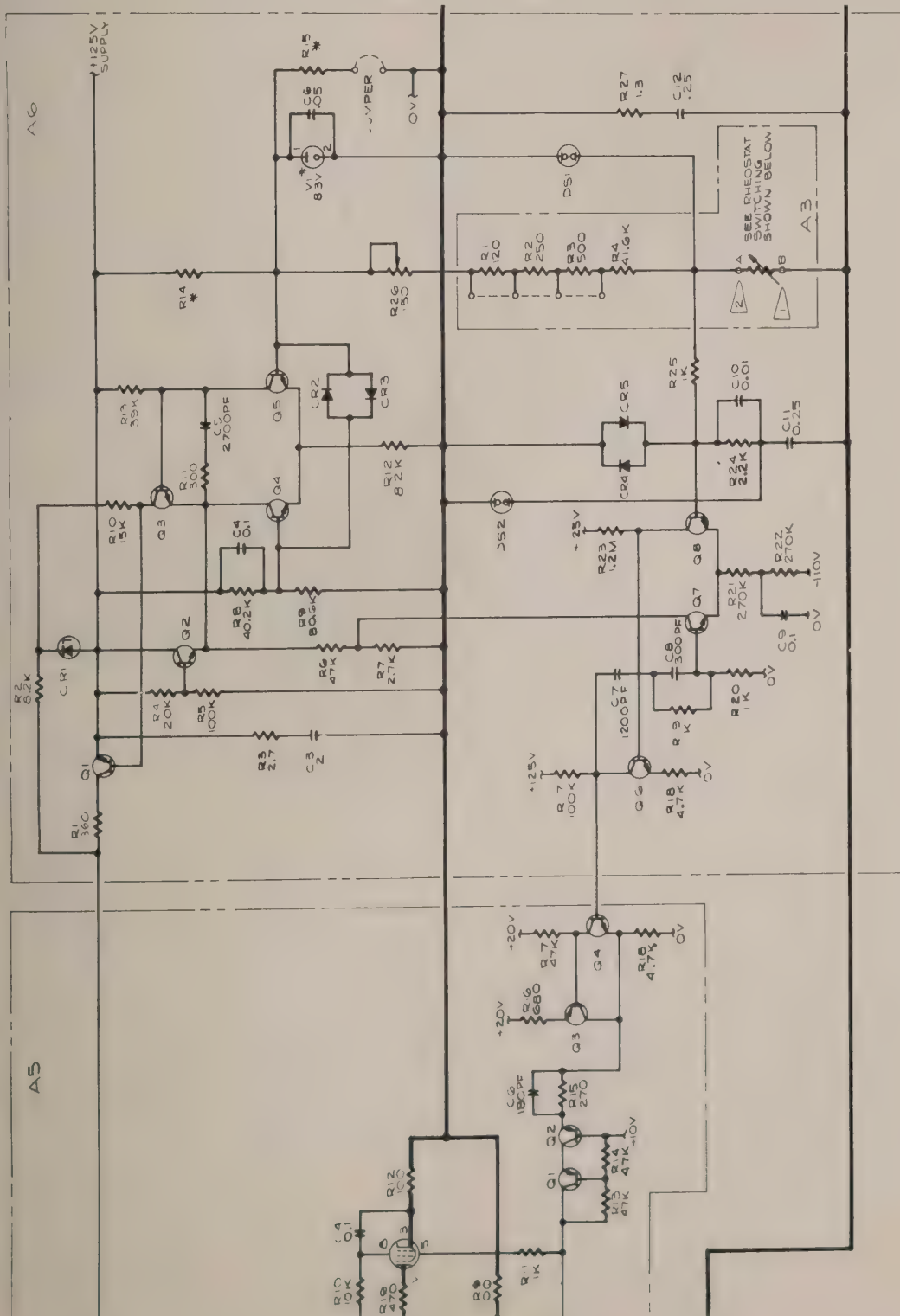


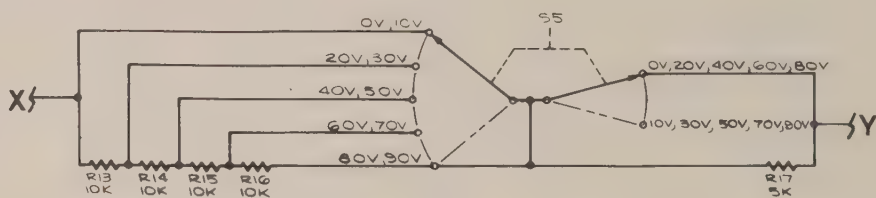
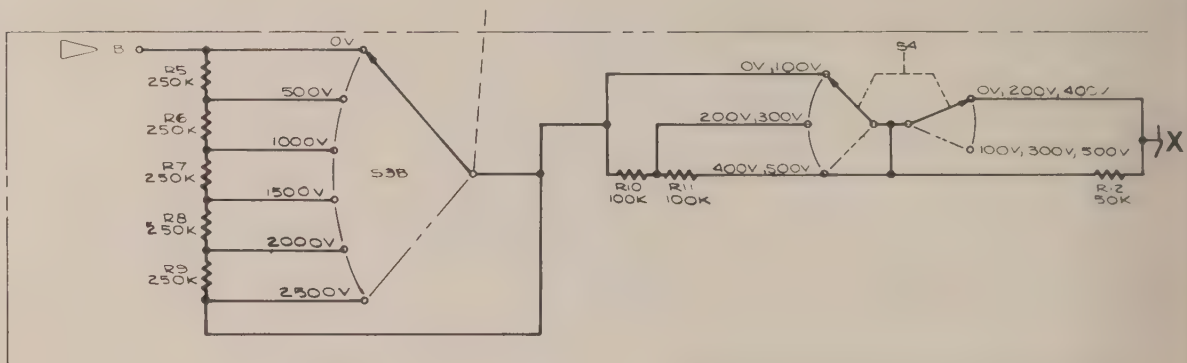
Figure 11. Error Sensing and Control Simplified Diagram



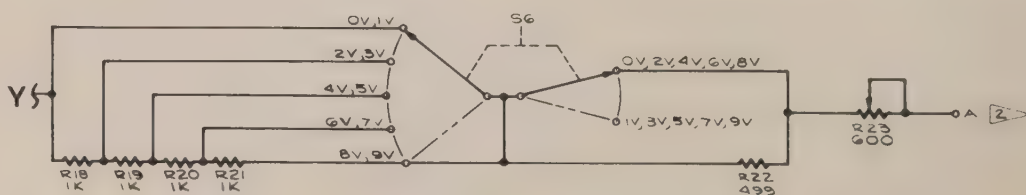
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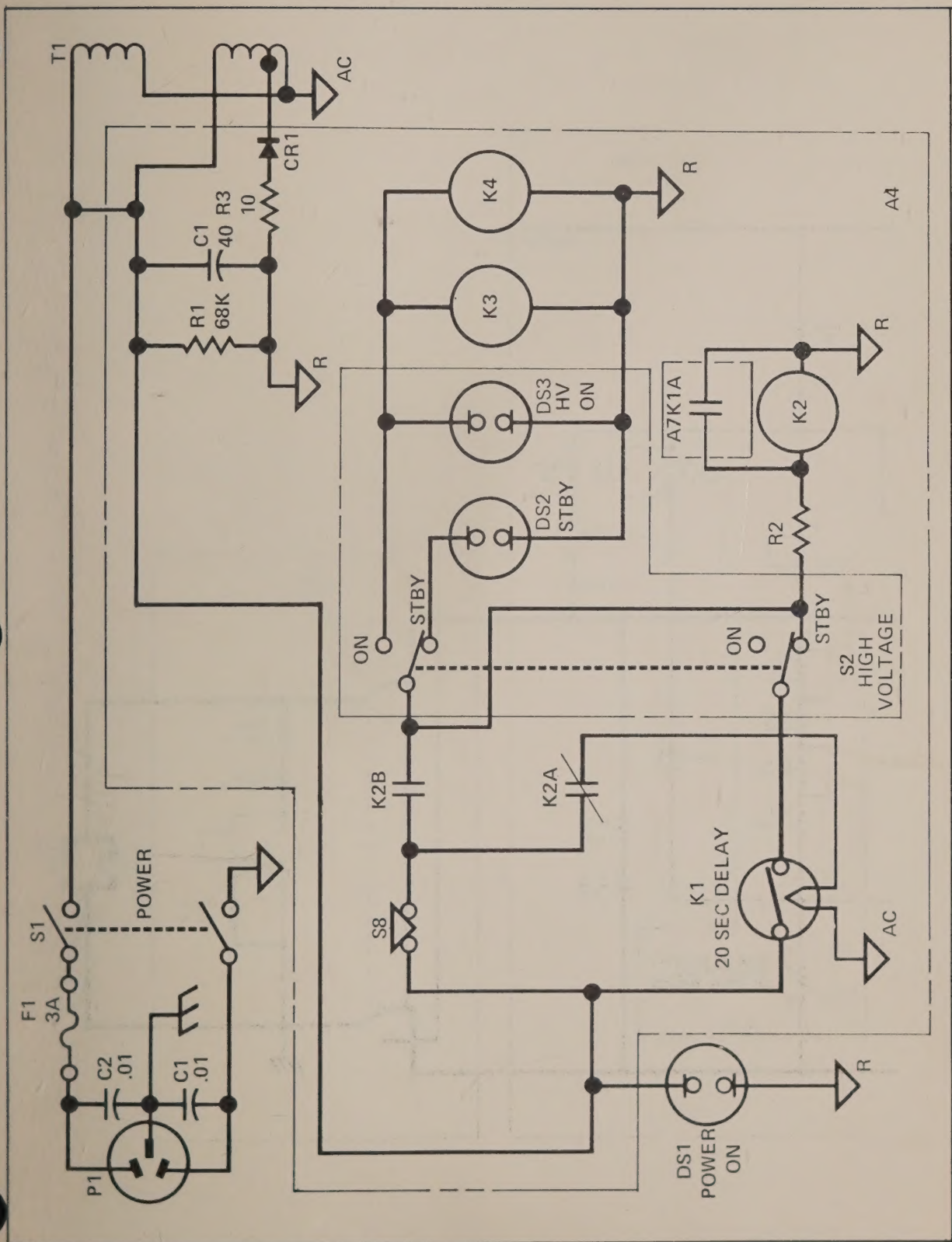
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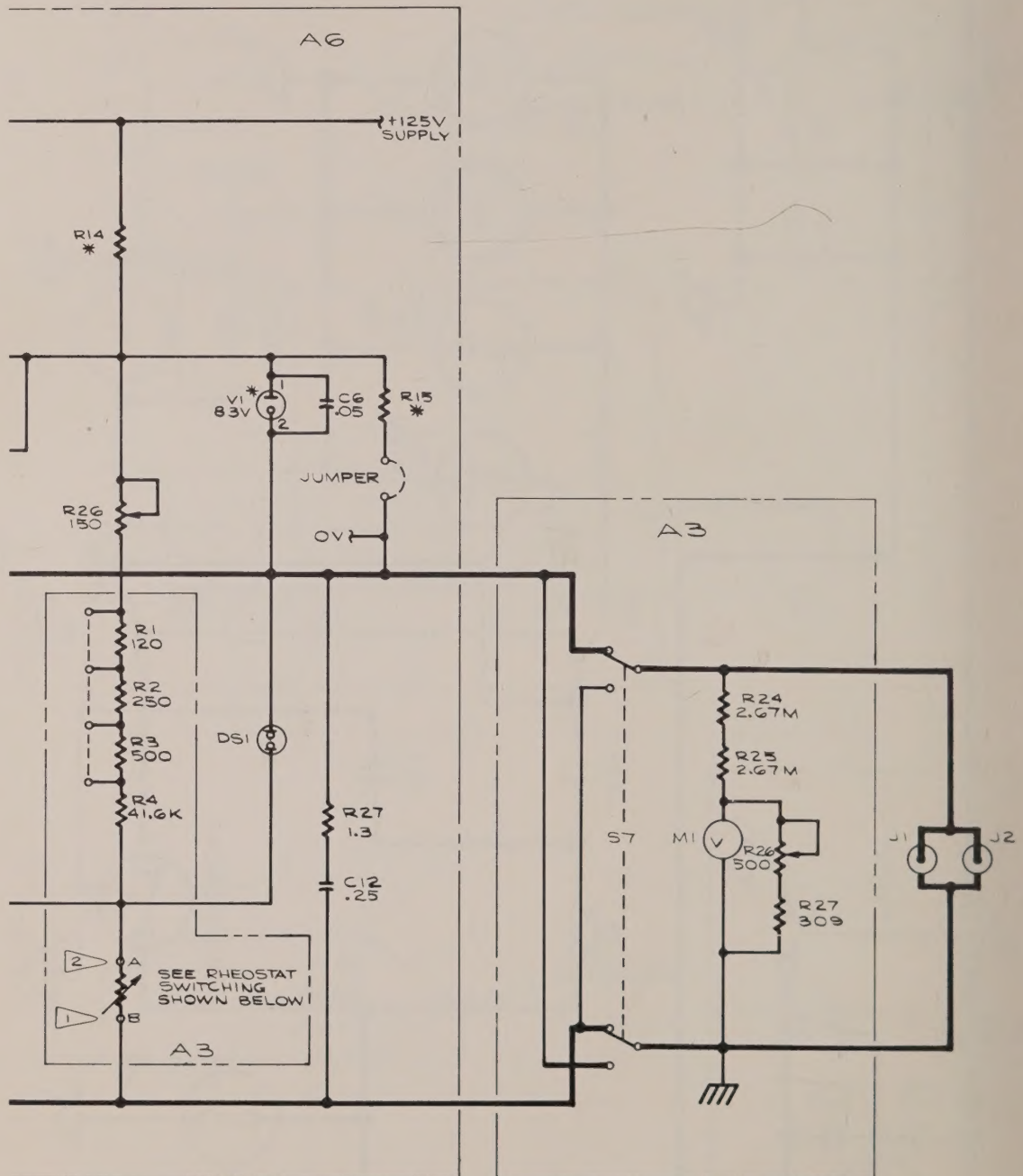
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Schematic No. 3



Schematic No. 4



Schematic No. 5

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